C Appendix C: Plant Tissue Sampling

The following is an excerpt from the *Guidance for Land Application of Municipal and Industrial Wastewater*, which can be accessed in its entirety at:

http://www.deq.idaho.gov/water/permits_forms/permitting/guidance_wlap.pdf

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$P_o = K(\psi) = 18$ inches/yr, or 5.22 E-3 cm/hr. If the vadose zone is composed of uniform sandy materials, we utilize Equation 2. Obtaining $A_k = 0.132$ E-2 and $\beta = 2.576$ from Guymon, 1994 p. 70, we solve for ψ, which is 168 cm. Next we utilize Equation 3, substituting ψ obtained from Equation 2, obtaining $\theta_s = 0.36$, $A_w = 0.0787$ and $\alpha = 0.614$ from Guymon (1994) p. 51. This expression is then solved for θ, which is 0.13.

Substituting P_o and θ into Equation 1, we obtain a pore velocity under steady-state conditions of 18 in/0.13, or 141.7 inches/year = 11.8 ft/year. If the vadose zone thickness were 50 feet then, utilizing Equation 4, the travel time to ground water would be 50 ft/(11.8 ft/yr), or 4.2 years.

7.5.7 References

Environmental Protection Agency. October 1981. Process Design Manual - Land Treatment of Municipal Wastewater, 625/1-81-013.

Gardner, W.R., 1958. Some Steady-States Solutions of the Unsaturated Moisture Flow Equation with Application to Evaporation from a Water Table. Soil Science, Vol. 85 pp. 223-232.

Guymon, G.L., 1994. Unsaturated Zone Hydrology. PTR Prentice Hall. 209 pages. (See Lumped Time of Travel Model. pp. 51, 71, 81-83, 103-104).

Idaho Department of Environmental Quality. March 14, 2001. Ground Water and Soils Quality Assurance Project Plan Development Manual. 121 pages.

Taylor, R. G. June 2003. Wastewater Land Application Statistical Guidance for Ground Water Quality Data. Idaho Department of Environmental Quality. X pages.

7.6 Plant Tissue Monitoring

Plant tissue monitoring is often required to make nutrient balance calculations Crop uptake calculations are utilized with soil nutrient data and other constituent loss estimates to arrive at leaching loss estimates. Nitrate, TKN, moisture, and ash contents are determined through chemical analysis of the harvested portion of generally one representative crop per wastewater land treatment site per harvest.

Wastewater land treatment sites that are loaded at agronomic rates or up to 150% of the agronomic rate are often required to performing the chemical analysis and make crop nutrient removal calculations. Some sites loaded at or below agronomic rates are allowed to use crop nutrient concentration values found in standard tables. It may be appropriate to use standard tables for crop nutrient concentration values when the purpose is simply to measure tonnage for a specific crop and assuming: (1) the published moisture content can be used from the table, and (2) soil monitoring is still done. One such standard table is found in Follett (1991) which is reproduced in Table 25. A second table (Table 26), designed for use with municipal permitting appears below. Table 25 below, has general values and is reproduced from the 1988 Guidelines.

7.6.1 REFERENCES

Follett, R.F., Keeney, D.R., and Crose, R.M., 1991. Managing Nitrogen for Ground Water Quality and Farm Profitability.

Idaho Division of Environmental Quality. 1988. Guidelines for Land Application of Municipal and Industrial Wastewater.

Table 25. Crop Nutrient Concentration Values

Estimated Nitrogen contents of the harvested portion of selected crops and vegetables. These values are approximate; actual site values will vary due to crop maturity, crop variety, climate (particularly water stress), and general nutrition status of crop.†

Source: Fonnesbeck et al. (1984), Natl. Acad. Sci. (1971); and many scientific papers in agronomy and crops too numerous to mention.

	N (Dry matter basis)				N harvested†	
Crop Description	Common value	General range	Unit of measure	Moisture content of unit	Common value	General range
	-------- % --------			%	----lb N/unit ---	
			Cereal and oil crops			
Barley, grain	2.10	1.90-2.30	Bu	14	0.87	0.78-0.95
Straw	0.73	0.58-0.88	Ton	10	13	10-16
Corn, Grain, Shelled	1.55	1.35-1.75	Bu	15	0.73	0.64-0.83
Silage	1.25	1.10-1.45	Ton	70	7.2	6.6-8.7
Oat, grain	2.20	1.95-2.50	Bu	14	0.61	0.54-0.69
Straw	0.70	0.55-0.85	Ton	10	13	9-15
Peanut, Seed with pods	4.20	3.40-5.00	100 lb	10	3.8	3.1-4.5
Seed only	4.60	3.80-5.40	100 lb	10	4.1	3.4-4.9
Rice, grain	1.40	1.05-1.65	Bu	14	0.54	0.41-0.64
Straw	0.65	0.50-0.80	Ton	10	12	9-14
Rye, grain	2.20	2.00-2.40	Bu	14	1.05	0.95-1.2

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Straw	0.50	0.35-0.65	Ton	10	9	6-12
Sorghum, grain	1.65	1.45-1.80	Bu	14	0.80	0.70-0.87
Soybean, grain	6.50	6.10-6.90	Bu	15	3.3	3.1-3.5
Straw	0.85	0.70-1.00	Ton	10	15	13-18
Sunflower, seed	2.70	2.20-3.20	Ton	10	49	40-58
Oil type						
Confection	3.20	2.80-3.60	Ton	10	58	50-65
Wheat grain, Hard red winter	2.30	2.05-2.50	Bu	14	1.2	1.1-1.3
Soft red winter	2.10	1.85-2.30	Bu	14	1.1	0.95-1.20
Soft white winter	1.80	1.60-2.00	Bu	14	0.95	0.80-1.05
Hard red spring	2.60	2.35-2.85	Bu	14	1.35	1.20-1.50
Straw	0.65	0.40-0.85	Ton	10	11	7-15
		Forage crops				
Alfalfa, Hay, sun-cured	3.30	2.80-3.80	Ton	15	56	48-65
Vegetative						
Early bloom	3.05	2.55-3.55	Ton	15	52	43-60
Mid bloom	2.75	2.25-3.25	Ton	15	47	38-55
Full bloom	2.50	2.00-3.00	Ton	15	43	34-51
Green chop						
Vegetative	3.55	3.05-4.05	Ton	75	18	15-20

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Early bloom	3.15	2.65-3.65	Ton	75	16	13-18
Mid bloom	2.90	2.40-3.40	Ton	75	15	12-17
Full bloom	2.60	2.10-3.10	Ton	75	13	10-16
Bermudagrass Hay, sun-cured Vegetative	2.50	1.90-3.10	Ton	15	43	32-53
Early to mid bloom	1.70	1.30-2.10	Ton	15	29	22-36
Full bloom to mature	1.10	0.80-1.40	Ton	15	19	14-24
Green chop Vegetative	2.75	2.10-3.40	Ton	75	14	11-17
Early to mid bloom	1.90	1.40-2.40	Ton	75	10	7-12
Full bloom to mature	1.25	0.90-1.60	Ton	75	6	5-8
Birdsfoot trefoil Hay, early bloom	3.10	2.60-3.60	Ton	15	53	44-61
Mid to full bloom	2.20	1.90-2.50	Ton	15	37	32-43
Green chop Early bloom	3.20	2.70-3.70	Ton	75	16	14-19
Mid to full bloom	2.30	1.95-2.65	Ton	75	12	10-13
Bluegrass, Kentucky Hay, sun-cured Mid bloom	1.75	1.40-2.00	Ton	15	30	24-34

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Mature	1.00	0.85-1.15	Ton	15	17	15-20
Hay, green chop Mid bloom	2.00	1.60-2.40	Ton	75	10	8-12
Mature	1.05	0.90-1.20	Ton	75	5	4-6
Bluestem						
Early bloom	1.40	1.10-1.70	Ton	20	22	18-27
Full bloom	1.10	0.90-1.30	Ton	20	18	14-21
Mature	0.70	0.60-0.80	Ton	20	11	10-13
Bromegrass, smooth, Hay, sun-cured Vegetative	3.05	2.60-3.50	Ton	15	52	44-60
Early bloom	2.10	1.75-2.45	Ton	15	36	30-42
Mid to late bloom	1.80	1.40-2.20	Ton	15	31	24-37
Mature	0.95	0.80-1.10	Ton	15	16	14-19
Hay, green chop Vegetative	3.35	2.85-3.85	Ton	75	17	14-19
Early bloom	2.25	1.90-2.60	Ton	75	11	9-13
Mid to late bloom	1.80	1.50-2.20	Ton	75	9	8-11
Mature	0.95	0.80-1.10	Ton	75	5	4.6
Clover Alsike						
Hay	2.40	2.05-2.75	Ton	15	41	35-47
Green chop	2.75	2.35-3.15	Ton	75	14	12-16
Crimson						

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Hay	2.65	2.25-3.05	Ton	15	45	38-52
Green chop	2.75	2.35-3.15	Ton	75	14	12-16
Ladino						
Hay	3.50	3.00-4.00	Ton	15	60	51-68
Green chop	4.00	3.50-4.50	Ton	75	20	17-23
Red, hay, sun- cured	3.35	2.85-3.85	Ton	15	57	49-66
Late vegetative						
Early to mid bloom	2.50	2.10-2.90	Ton	15	42	36-49
Full bloom	2.35	1.95-2.75	Ton	15	40	33-47
Red, green chop	3.40	2.90-3.90	Ton	75	17	15-20
Late vegetative						
Early to mid bloom	2.60	2.20-3.00	Ton	75	14	11-15
Full bloom	2.40	2.00-2.80	Ton	75	12	10-14
Sweet, hay	2.65	2.25-3.05	Ton	15	45	38-52
Green chop	2.90	2.50-3.30	Ton	75	15	13-17
White, hay	3.40	2.90-3.90	Ton	15	58	49-66
Green chop	4.00	3.50-4.50	Ton	75	20	18-23
Corn, silage	1.25	1.10-1.45	Ton	70	7.5	6.6-8.7
Fescue, tall						
Hay, late vegetative	2.70	2.20-3.20	Ton	15	46	37-54
Mid bloom	1.50	1.20-1.80	Ton	15	26	20-31
Mature	1.00	0.80-1.20	Ton	15	17	14-20

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Green chop Late vegetative	2.90	2.30-3.50	Ton	75	15	12-18
Mid bloom	1.70	1.40-2.00	Ton	75	9	7-10
Mature	1.10	0.90-1.30	Ton	75	6	5-7
Orchardgrass Hay, late vegetative	2.40	1.90-2.90	Ton	15	41	32-49
Mid bloom	1.60	1.30-1.90	Ton	15	27	22-32
Mature	1.20	1.00-1.40	Ton	15	20	17-24
Green chop Late vegetative	2.50	2.00-3.00	Ton	75	13	10-15
Mid bloom	1.70	1.40-2.00	Ton	75	9	7-10
Mature	1.20	1.00-1.40	Ton	75	6	5-7
Peanut, hay	1.85	1.50-2.20	Ton	15	31	26-37
Ryegrass Hay, late vegetative	1.85	1.50-2.20	Ton	15	31	26-37
Mid bloom	1.30	1.00-1.60	Ton	15	22	17-27
Green chop Late vegetate	2.00	1.60-2.40	Ton	75	10	8-12
Mid bloom	1.40	1.10-1.70	Ton	75	7	6-9
Sorghum, silage	1.00	0.70-1.30	Ton	74	5.2	3.5-6.8
Sorghum-sudan Green chop Immature	2.65	1.90-3.45	Ton	82	9.5	6.8-12

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Mid-mature	1.40	1.00-1.80	Ton	77	6.4	4.6-8.3
Silage	1.50	0.95-2.05	Ton	77	6.9	4.5-9.5
Timothy						
Hay, sun-cured	2.25	1.90-2.60	Ton	15	38	32-44
Vegetative						
Early to mid bloom	1.55	1.30-1.90	Ton	15	26	22-32
Late bloom	1.20	1.00-1.40	Ton	15	20	17-24
Mature	0.95	0.80-1.10	Ton	15	16	14-19
Hay, green chop	2.30	1.95-2.65	Ton	75	12	10-13
Vegetative						
Early to mid bloom	1.70	1.35-2.00	Ton	75	9	7-10
Late bloom	1.25	1.05-1.45	Ton	75	6	5-7
Mature	0.95	0.80-1.10	Ton	75	5	4-6
Vetch						
Common						
Hay, early bloom	3.60	3.10-4.10	Ton	15	61	53-70
Full bloom	2.90	2.50-3.30	Ton	15	49	43-56
Green chop						
Early bloom	3.70	3.10-4.20	Ton	75	19	16-21
Full bloom	3.00	2.60-3.40	Ton	75	15	13-17
Hairy fresh						
Mid bloom	3.70	3.10-4.20	Ton	75	19	16-21
Wheatgrass, crested	1.60	1.30-1.90	Ton	20	26	21-30
Hay, early						

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
bloom						
Full bloom	1.40	1.10-1.70	Ton	20	22	18-27
Mature	0.60	0.50-0.70	Ton	20	10	8-11
		Fiber and miscellaneous crops				
Cotton, lint	0.20	0.15-0.25	100 lb	10	0.2	0.1-0.2
Seed	3.70	3.40-4.00	100 lb	10	3.3	3.1-3.6
Flax, seed	3.80	3.30-4.30	100 lb	7	3.5	3.1-4.0
Peanut						
Seed with pods	4.20	3.40-5.00	100 lb	10	3.8	3.1-4.5
Seed only	4.60	3.80-5.40	100 lb	10	4.1	3.4-4.9
Hay	1.85	1.50-2.20	Ton	15	31	26-37
Potato, white tubers	1.60	1.20-1.90	100 lb	75	0.4	0.3-0.5
Sugarbeet						
Tops w/crown	2.10	1.80-2.30	Ton	82	7.6	6.5-8.3
Roots w/o crown	0.80	0.60-0.95	Ton	77	3.7	2.8-4.4
Tops w/o crown	2.50	2.20-2.80	Ton	82	9.0	7.9-10.1
Roots w/crown	1.10	0.90-1.30	Ton	77	5.1	4.1-6.0
Sugarcane						
Millable cane						
<12 mo crop	0.35	0.28-0.40	Ton	72	2.0	1.6-2.2
>12 mo crop	0.25	0.20-0.30	Ton	70	1.5	1.2-1.8
Cane tops + trash	0.90	0.70-1.10	Ton	75	4.5	2.5-5.5

Crop Description	N (Dry matter basis) Common value	General range	Unit of measure	Moisture content of unit	N harvested† Common value	General range
	-------- % --------			%	----lb N/unit ---	
Sunflower, seed	2.70	2.20-3.20	Ton	10	49	40-58
Oil type						
Confection	3.20	2.80-3.60	Ton	10	58	50-65
Tobacco						
Flue-cured	2.0	1.7-2.3	100 lb	20	1.6	1.4-1.8
Maryland type	3.1	2.6-3.6	100 lb	18	2.5	2.1-3.0
Burley	4.0	3.5-4.5	100 lb	25	3.0	2.6-3.4
			Vegetable crops			
Asparagus	5.50	4.80-6.20	Ton	92	8.8	7.7-7.9
Bean, snap, pods	3.00	2.50-3.50	Ton	87	7.8	6.5-9.0
Dry bean seed	4.00	3.50-4.50	100 lb	10	3.6	3.2-4.1
Beet, red table, roots	1.95	1.65-2.25	Ton	87	5	4-6
Tops	3.50	3.00-4.00	Ton	85	11	9-13
Broccoli	5.90	5.10-6.80	Ton	90	12	10-14
Cabbage, head	2.80	2.30-3.30	Ton	91	5.0	4.1-5.9
Cantaloupe	1.45	1.20-1.70	Ton	90	2.9	2.4-3.4
Carrot, roots	1.50	1.30-1.70	Ton	88	3.6	3.1-4.1
Foliage	2.30	2.00-2.60	Ton	84	7.4	6.4-8.3
Cauliflower	4.40	3.80-5.00	Ton	91	7.9	6.8-9.0
Cucumber	2.40	2.00-2.90	Ton	95	2.4	2.0-2.9
Lettuce, head	4.10	3.30-4.90	Ton	95	4.1	3.3-4.9
Onion, bulbs	2.20	1.90-2.50	Ton	90	4.4	3.8-5.0
Pea, seed only	4.20	3.50-4.70	Ton	80	17	14-19

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested† Common value	N harvested† General range
	-------- % --------			%	----lb N/unit ---	
Vine-no pods	2.00	1.50-2.50	Ton	75	10	8-13
Pepper, sweet green	2.30	1.90-2.70	Ton	92	3.7	3.0-4.3
Spinach	4.70	3.90-5.50	Ton	91	8.5	7.0-9.9
Squash, summer	3.10	2.70-3.50	Ton	92	5.0	4.3-5.6
Winter	2.10	1.70-2.50	Ton	88	5.0	4.1-6.0
Sweet corn, stover	1.30	1.10-1.50	Ton	70	7.8	6.6-9.0
Ears with husks	1.60	1.40-1.80	Ton	73	8.6	7.6-9.7
Sweet potato, root	1.10	0.90-1.30	Ton	72	6.2	5.0-7.3
Tomato	2.70	2.30-3.10	Ton	94	3.2	2.8-3.7
Watermelon	1.25	1.00-1.50	Ton	91	2.3	1.8-2.7
		Tree and fruit crops				
Apple	0.35	0.25-0.45	Ton	82	1.3	0.9-1.6
Almond, with shell	3.30	3.00-3.60	Ton	15	56	51-61
Cherry	1.15	1.00-1.30	Ton	82	4.1	3.6-4.7
Grapefruit	1.20	1.00-1.40	Ton	88	2.9	2.4-3.4
Grape	0.60	0.50-0.70	Ton	80	2.4	2.0-2.8
Lemon	1.50	1.30-1.70	Ton	87	3.9	3.4-4.4
Orange	1.20	1.00-1.40	Ton	82	4.3	3.6-5.0
Peach	1.00	0.80-1.20	Ton	88	2.4	1.9-2.9
Pear	0.40	0.30-0.50	Ton	82	1.4	1.1-1.8
Pecan, with	2.80	2.50-3.10	Ton	15	48	43-53

Crop Description	N (Dry matter basis) Common value	N (Dry matter basis) General range	Unit of measure	Moisture content of unit	N harvested‡ Common value	N harvested‡ General range
	-------- % --------			%	----lb N/unit ---	
shell						
Strawberry	1.35	1.10-1.60	Ton	91	2.4	2.0-2.9

†Percent N and N harvested will generally be above the common value for crops grown on N-rich soils (luxury amounts of manure, fertilizer, etc.) and for crops grown in water-stress conditions (low dry matter production); percent N and harvested N will generally be below the common value for crops grown in N poor soils (low N inputs (and for crops with above-average dry matter production (good rainfall years, irrigation, etc.)

‡CH_h as defined in Chapter 12 by Pierce et al., is the N removed in the harvested biomass.

Table 26. Typical Nitrogen Uptake Values for Various Crops (for municipal permitting)

Crop Type	Data Source	Yield Unit	Nitrogen Uptake, lbs per yield unit	Comments
Wheat	1	Bushel/acre	1.2	89% dry matter, 60 lbs/bu
Barley	1	Bushel/acre	0.9	89% dry matter, 48 lbs/bu
Oats	1	Bushel/acre	0.6	89% dry matter, 32 lbs/bu
Field Corn (for grain)	1	Bushel/acre	0.8	87% dry matter, 56 lbs/bu
Field Corn (for silage)	1	Tons/acre	7.1	28% dry matter
Alfalfa Hay	1	Tons/acre	50.4	90% dry matter
Alfalfa (Green Chop)	2, 3	Tons/acre	14	25% dry matter
Grass Silage	1	Tons/acre	13.6	50% dry matter
Tall Fescue	2, 3	Tons/acre	46	85% dry matter
Orchardgrass	2, 3	Tons/acre	41	85% dry matter
Clover Hay	2, 3	Tons/acre	41	85% dry matter
Crested Wheatgrass	2, 3	Tons/acre	26	80% dry matter
Trees	4		80 to 220	
Rangeland,	1		24	

1. Taken from the 1992 Census of Agriculture, refer to the following website: http://www.nhq.nrcs.usda.gov/land/pubs/nlappla.html
2. Fonnesbeck et al (1984)
3. Part 651, Agricultural Waste Management Field Handbook
4. From various references for poplars, other deciduous trees, conifers, and woodlands.

D Appendix D: Winterization and Maintenance of Equipment

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Winterization and Maintenance of Sprinkler Irrigation Equipment

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An irrigation system is an expensive investment. Regular maintenance and following recommended off-season storage procedures will help keep your system operating properly for many years. Following these procedures also reduces the risk of equipment failures that may lead to lost production time or crop loss. These procedures are particularly critical in wastewater application systems, where equipment failures could result in a discharge of liquid wastes and damage to the environment.

This publication provides general checklists for routine equipment inspections, regular maintenance schedules and winterization procedures for surface irrigation systems used for applying fresh water and those applying animal, industrial or municipal wastewater. Turf, landscape, surface drip, and subsurface drip irrigation systems are not covered.

The original operation and maintenance manual for a piece of irrigation equipment is your primary source of information regarding its required maintenance procedures. If the manual can not be located, ask your local dealer or equipment manufacturer for a replacement.

Solid Set Irrigation Systems

Stationary irrigation systems are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). The stationary sprinkler systems is often used in irregularly shaped fields, making it difficult to give a standard layout, but there are some common features between systems. To provide proper overlap, sprinkler spacings are normally 50 to 65 percent of the sprinkler's wetted diameter. Sprinkler spacing is based on nozzle flow rate and desired application rate. Impact sprinkler spacings are typically in the range of 80 feet by 80 feet using single-nozzle sprinklers. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals, and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed. In many wastewater application systems, ball valves are installed on sprinkler risers along buffers, hillsides, or other areas where runoff or ponding is a concern.

Table 1. Annual Maintenance Procedures for Sprinklers.

Type of Sprinkler	Procedures
Pressure Gauges	Check pressure gauge, pressure transducer, or flow meter for proper operation. Follow manufacturer's guidelines for calibrating transducers or flowmeters.
Big Guns	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace ring if worn. 2) Check reverse rotation of gun. The gun should travel in both directions (left to right, and right to left) at the same speed. Big guns operating in partial circles (less than 360°) tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to keep out of dirt or small animals.
Impact Sprinklers	1) Check nozzles for wear. Replace dented or worn brass nozzles. Check plastic nozzles for cracks, chips, or wear patterns. Replace if necessary. 2) Check rotation of each sprinkler. Swing the impact arm 4 inches to the right and release. The sprinkler head should freely and fluidly move several inches. Repeat. Ensure that the amount of rotation is consistent each time the impact arm is released. If the amount of rotation is not consistent or not fluid, replace the sprinkler head. 3) Tape over the sprinkler nozzle and pipe base to keep out foreign objects, such as insects, rodents, dust and dirt. Remove tape before operating.

Hard-Hose Travelers

Hard-hose travelers are the most popular pieces of irrigation equipment for applying animal wastes and lagoon effluent. Properly designed and installed hard-hose travelers are one of the most efficient and reliable methods of irrigating large areas. Hard-hose travelers are expensive and highly specialized pieces of equipment that cost $12,000 to $26,000. Maintenance will ensure that your equipment lasts for many years and operates properly. Proper maintenance of irrigators will also insure that waste can safely be applied, minimizing discharges or runoff events caused by malfunctioning equipment. Table 2 provides a schedule for lubricating and checking various necessary fluids on turbine-drive and engine-drive hard-hose travelers. Consult your equipment's operation and maintenance manual and follow the specific lubrication schedule that should be followed for your irrigator.

Table 2. Lubrication and Fluids Schedule for Hard-Hose Travelers.

LOCATION	TYPE OF LUBRICANT	DAILY	EVERY TWO WEEKS	MONTHLY	YEARLY
Inlet Spindle Thrust Washer	Multipurpose Grease			X	
Inlet Swivel	Multipurpose Grease		X		
PTO Shaft (if present)	Multipurpose Grease	X			
Traverse Assembly	Multipurpose Grease		X		
Drum Bearings	Multipurpose Grease			X	
Chains (except drum)	30 wt. Oil			X	
Wheel Bearings	Multipurpose Grease				X
Turntable Bearing Ring	Multipurpose Grease			X	
Gearbox (2)	90 wt. Oil				X
Gun Cart Wheel Bearings	Multipurpose Grease			X	
Drive Engine Oil	Follow Manufacturer's Specification	X			

Center-Pivot and Linear-Move Systems

Center-pivot and linear move systems are becoming more common in North Carolina. Center-pivots are available in both fixed-pivot point and towable machines. Linear-move systems are similar to pivots but instead of moving in a circular pattern they move only forward and reverse. Pivots and linears area powered electrically (480 V-AC or diesel generator) or by a diesel-powered hydraulic drives. They range from single tower machines that cover around 10 acres to multitower machines that can cover several hundred acres. Pivots and linears use either rotary sprinklers, small guns, or spray nozzles. Drop-type spray or rotary nozzles offer the advantage of applying water close to the ground at low pressure, which results in less evaporative losses and little drift due to wind. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 pound per square inch (psi). Low pressure systems (10 – 30 psi) reduce drift at the expense of higher application rates and greater potential for runoff.

DISCONNECT POWER WHEN PERFORMING MAINTENANCE. ALWAYS disconnect electrical power before servicing or performing maintenance to the machine. If you are going to perform maintenance to the machine, YOU shut off and lock the main power disconnect. Don't trust someone else to turn the power off for you. DO IT YOURSELF and take the key with you!

Table 3. Seasonal Maintenance Checklist for Center-Pivots and Linear-Move Systems.

LOCATION	ACTION
Tower	
Ground Cable	Ensure #6 bare copper wire is connected to main panel and ground rod.
Tie-downs & Turnbuckles	All tie-down bolts (turnbuckles on towable units) are drawn up tight.
Pivot Head/swivel	Grease pivot head and ensure that collector ring is in place.
Span	1. Check flanges for leaks and tighten as necessary. 2. Check pipe drains for proper drainage and rotate the seal each season. 3. Tighten all tower and span bolts and cables. 4. Check power cable for damage and proper banding to ensure proper attachment to span.
Wheels	1. Check tire pressure. Check maintenance manual for proper pressure. 2. Tighten wheel lug bolts. All wheel lugs should be torqued to 125 foot-pounds annually. 3. Check wheel gearbox oil level. Drain annually or every 1,000 hours, whichever occurs first.
Drive Motors	1. Check flex boots for leaks and tighten bands as necessary. 2. Check motor power and ground cables for damage and good connection. 3. Check gear motor lubricant. Replace lubricant after the first year of operation and then every 3 years or 3,000 hours, which ever occurs first. Consult manufacturer for appropriate gear lubricants.
Sprinklers	1. Check sprinklers, nozzles, pressure regulators for tightness. 2. Check sprinklers for free movement. 3. Check sprinkler nozzles for damage or wear. 4. Check pressure gauge or pressure transducer for proper operation.
End Gun & Booster Pump	1. Check overhang cables for damage and proper banding. 2. Clean and ensure proper operation of end gun drain. Flip drain annually. 3. Check end gun nozzle for wear. 4. Check end gun arc setting, bearings, and brake.

Pumps

A well maintained pumping system lasts longer and needs fewer repairs. This means less downtime that may limit your ability to apply animal wastes when environmental conditions are optimal.

Set up weekly, quarterly, and annual routine maintenance and inspection schedules for systems that are run more than twice a week (Table 4). If your pump is operated less often, inspect those items listed as weekly and quarterly every 2 months. Regardless of the amount of time a pump is used, a certified operator should conduct an annual inspection of the pumping and siphon system. As stated earlier, refer to the operation and maintenance manual provided with your pump for the lubrication and maintenance required for your pump.

Table 4. Weekly, Quarterly, and Annual Maintenance for Agricultural Pumps.

Weekly	
Stuffing Box	Pumps with packing rings should leak a small amount of water while the pump is in operation. If water is not dripping from the seal, loosen the gland nuts evenly until water is just running out of the snuff box in a DROPLET form. Water should not be streaming or spraying out. Approximately 20 drops per minute is recommended for most pumps. Adjust the gland nuts EVENLY as necessary to maintain this drop rate and provide necessary lubrication and cooling of the packing. If packing is tightened to the limit of the packing gland travel, additional packing is necessary.
Mechanical Seals	Pumps with mechanical seals, instead of packing rings and snuff boxes, should not leak. If leaks are detected, ensure that the pump housing bolts are tightened thoroughly. If leaks still continue, contact your pump provider or distributor.
Vibration	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Suction Line	Inspect line and screen for flow obstruction.
Quarterly	
Piping Connections	Inspect all system piping connections for leaks and misalignment. Misalignment of pipe connections will put excessive strain on the pump case and may cause damage to internal components of both the pump and motor. If stress on the pump case is suspected, adjust pipe supports to correct. For flange connections, shut down the pump, and remove the pipe flange bolts on the pump connections to check for misalignment. If the mating flanges come apart or shift, there is pressure at the connection(s) and adjustments should be made to the pipe supports until flanges mate without force.
Pump Foundation	Check foundation and for soundness and see that all securing bolts or lags are secure.
Lubrication	Complete all quarterly lubrications recommended in your operation and maintenance manual for you pump.
Snuff Box and Mechanical Seals	Inspect pump packing gland or mechanical seal for possible replacement. Examine shaft sleeve, if present, for wear and replace if necessary.
Pump and/or Motor Bearing	Inspect bearings for signs of wear. Repack or replace as required.
Annually	
Pumping System	Inspect the entire pump and pumping system for signs of wear.
Valves	Inspect system valves, screens, etc. Ensure that all valves are fully operational and not frozen. Lubricate or replace if necessary.
Impeller	Check pump impeller eye or proper clearance. Specific clearance specifications can be found in the pump's operation and maintenance manual or from the pump manufacturer or local distributor.
Pump Housing	Inspect pump impeller, volute case (housing), and seal chamber for signs of excessive wear or corrosion.
Hand Primer	Ensure the hand primer is operating properly. Disassemble and inspect the diaphragm for excessive wear or cracks. Replace if necessary.

Power Units

Both diesel engines and electric motors are used to power irrigation pumps. A well maintained engine system lasts longer and needs fewer repairs. The following tables provide a routine and annual maintenance and inspection schedule for pumps with electric motors (Table 5) or diesel engines (Table 6). The required maintenance and lubrication procedures should be followed daily, yearly, and for various intervals of engine operating time.

Table 5. Inspection and Maintenance Schedule for Electric Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	PROCEDURE
Motor Bearings	Quarterly	Inspect motor bearings for signs of wear. Repack or replace as required.
Pump Foundation	Quarterly	Check the electric motor's foundation and for soundness. See that all securing bolts or lags are secure.
Lubrication	Quarterly	Complete all quarterly lubrications recommended in your operation and maintenance manual for your motor/pump.
Vibration	Quarterly	All rotating machines produce some amount of vibration. Excessive vibration, however, can reduce the life of your pumping and power unit. If a vibration seems excessive, stop operation, determine the cause, and correct.
Noise	Quarterly	When the unit is in operation, listen closely for unusual sounds that might indicate the unit is operating improperly. Determine the cause and correct.
Motor Windings	Annually	Check motor windings for degradation, rewind if necessary.
Terminal Connections	Annually	Check to ensure that terminal screws and wire connections are tight. After several years, normal heat and temperature fluctuations tend to loosen terminal screws and wire connections.

Winterization and Storage Procedures

To prevent damage, properly store your irrigator, engine, and pump anytime it will not be operating for several months. Preparing equipment for winter storage also allows you to conduct annual inspections and make necessary repairs. If possible, remove equipment from the field and store it in a clean, dry, covered storage area. The following tables (Tables 7 – 10) will help you minimize corrosion and deterioration of hard-hose travelers, irrigation pumps and diesel-powered pumping units.

Table 6. Inspection and Maintenance Schedule for Diesel Motors that Power Irrigation Pumps.

REQUIRED ACTION	SCHEDULE	NOTES
Check Engine Oil and Coolant Level	Daily	
Check Fuel Filter	Daily	
Lubricate PTO Release Bearing	Daily	DO NOT over-lubricate and avoid getting oil on clutch facings.
Check Dust Unloader Valve on Air Cleaner (if installed)	Daily	Check for air leaks and degraded rubber.
Lubricate PTO Clutch Shaft Bearings	Every 100 Hours	
Change Initial Engine Oil and Filter	Every 100 Hours	Initially change engine oil after 100 hours and then every 250 hours thereafter. Ensure that oil filter meets engine performance standards; refer to operation and maintenance manual.
Service Fire Extinguisher	Every 100 Hours	
Service Battery	Every 250 Hours	
Change Engine Oil and Filter	Every 250 Hours	Check operation and maintenance manual for recommended weight oil and approved filters.
Check Fan and Alternator Belt Tension.	Every 250 Hours	Do not pry against alternator rear frame. Once adjusted, recheck tightness of belts after operating 10 minutes.
Check PTO Clutch Adjustment	Every 250 Hours	Measure clutch engagement force at the handle grip using a spring scale. Force should be between 60 – 70 lbs.
Initial Engine Valve Clearance	400 Hours	Initially check valve clearance after 400 hours and then every 1,200 hours thereafter. Consult engine operation and maintenance manual or dealer.
Lubricate PTO Clutch Internal Levers and Linkage	Every 600 Hours or Annually	
Clean Crankcase Vent Tube	Every 600 Hours or Annually	
Check Air Intake Hoses and Connections	Every 600 Hours or Annually	The air intake system must not leak. Even the smallest leak may cause dame to the engine.
Replace Fuel Filter Element	Every 600 Hours or Annually	
Check Cooling System	Every 600 Hours or Annually	
Check Coolant Solution	Every 600 Hours or Annually	Add inhibitor as needed
Replace Air Cleaner Elements and Check Air Intake System	Every 600 Hours or Annually	
Perform Engine Tune-Up	Every 1,200 Hours or Every Other Year	
Check and Adjust Engine Speeds	Every 1,200 Hours or Every Other Year	Consult engine operation and maintenance manual or dealer.
Adjust Engine Valve Clearance	Every 1,200 Hours or Every Other Year	
Check Fuel Injection System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect Turbocharger (if installed)	Every 1,200 Hours or Every Other Year	Check for excessive radial or axial play of compressor wheel and turbocharger boost pressure. Consult your servicing dealer or distributor.
Check Crankshaft Vibration Damper	Every 1,200 Hours or Every Other Year	Grasp vibration damper with both hands and attempt to turn in both directions. If rotation is felt, replace damper. Replace damper every 4,500 hours or every 5 years.
Flush Cooling System and Replace Thermostats	Every 1,200 Hours or Every Other Year	Flush with water before using a heavy duty cooling system cleaner. Fill system with only approved coolants.
Check Pressure Test Cooling System	Every 1,200 Hours or Every Other Year	Consult your authorized engine repair station, servicing dealer, or distributor.
Inspect and Service Air Cleaner Elements	As Required	When cleaning and washing primary element, remember to wash is a solution of warm water and filter element cleaner. NEVER use compressed air, gasoline, or other solvents. DO NOT oil element.

Table 7. Winterization and Storage Procedures for Hard-Hose Travelers.

REQUIRED ACTION	PROCEDURE
Purging Hose	The best method of removing water from a hard hose traveler is purging the hose with compressed air. If your irrigator is not equipped with an air-purging cap, ask your equipment distributor if one is available. Air purging will allow you to remove 85% of all of the water from your reel without risking damaging the hose when rolling up dry or from miswraping. 1. Retract hose from field and lower cart to the ground. Ensure that the cart/hose is pointed away from farm workers, vehicles, equipment, and structures. 2. Remove drain cap on cart or open drain valve. 3. Attach air-purging cap to the inlet of the irrigator. Attach hose from compressor to air-purging cap. 4. Start air compressor and build up at least 100 psi of pressure. When achieved, open valve and begin to purge the water from the irrigator. 5. DO NOT STAND near or in front of the cart during purging. Once pressure is built up in the hose, water will be blown from the irrigator at a great force. 6. Once water is blown from the reel, finish retracting the hose and cradle gun cart. Continue with off-season storage procedures.
Draining Hose	Follow this procedure only if your equipment cannot be purged with compressed air. 1. Tow the hose out to the full length and open plug or drain valve on cart. **NOTE: Leave at least ¾ coil of hose on the drum to prevent pulling the hose off of the reel. 2. Rewind hose slowly with PTO or engine drive. This will allow water to drain from the reel and prevent damage from freezing. 3. DO NOT leave the reel unattended during the draining process. The hose will have a tendency to flatten slightly and miswrap. You may need to manually adjust the hose position on the drum using a wooden pole to pry the hose in place. 4. Check hose for any cracks, damage ,or loose connections. Replace or repair as necessary. 5. Replace/close drain plug or drain valve. 6. After removing the irrigator from storage, a full pull of the traveler should be made. This will ensure that no changes occur to the mechanical speed compensation devices on the equipment.
Drive Turbine	Open gate valve and drain plug or petcock on turbine assembly.
Fittings	Lubricate all fittings with multipurpose grease or appropriate weight oil.
Chassis	Touch up any scratched or chipped paint and repaint any rusted areas.
Big Gun	1) Check nozzle for wear. You may need to use machinist's calipers to check ring nozzles for appropriate diameter. Replace any worn rings. 2) Check reverse rotation of gun. The gun should travel left to right and right to left at the same speed. Big guns operating in partial circles tend to unevenly wear bearings, adversely affecting the speed of gun rotation. If bearings are worn, it may be necessary to replace the entire gun. 3) Cover the inlet of the gun to prevent the entrance of dirt or small animals.
Tires	1. Check tires for wear and cracks. 2. Reduce tire pressure to 15 psi for off-season storage. Inflate tires to 40 – 45 psi before operating.
Drive Engine	1. Change engine oil. 2. Clean/replace air filter as necessary.
Safety Shields	Check for the presence of all manufacturer's safety shields. Tighten and replace safety shields as necessary.
Chains	(Optional) Remove and store all chains in a lubricant, such as diesel fuel.
Storage	1. Store reel in a clean, dry place. 2. Block irrigator to remove the weight of the machine from the wheels. 3. If the reel is left outside, cover the entire machine with a waterproof canvas.

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Table 8. Winterization and Storage Procedures for Center Pivot and Linear Move Systems.

REQUIRED ACTION	PROCEDURE
Flushing	Flush after pump repair, structural repair, winterization, season start-up, and as often as necessary to remove accumulated sand and debris. Excessive sprinkler clogging or wear can indicate high debris or sand content. 1. Turn main power off! Only water is required to flush the unit – the pivot/linear does not need to run. Ensure that the machine is not under water pressure. REMOVING SAND TRAP PLUGS WHILE UNDER PRESSURE MAY CAUSE INJURY OR DEATH! 2. Remove pipe drains at each tower. Clean sand and foreign particles from these drains. Flip rubber seals when reinstalling (step 6). 3. Remove the sand trap from the last regular drive tower. Clean sand and foreign particles from these drains and spray nozzles (if installed). 4. Remove the plugs in the overhang. 5. Start the engine/pump and allow the machine the flush thoroughly. 6. Turn off water supply. Reinstall all pipe drains, sand traps, and plugs. After flushing for winterization, be sure the water has drained completely from all drains before replacing drains and plugs to prevent freezing and splitting of the pipeline.
Booster Pump	Drain the booster pump. Ensure supply line is not plugged with sand or debris. Remove drain plug.
Valve or Sensor Strainers	Selenoid valve or sensor strainers should be cleaned at least once a year. Remove the strainer housing and wash strainer by running fresh water through the strainer. Avoid scrubbing the strainer to remove collected particles for this may damage the mesh.
Towable Hubs	Towable hubs should be greased thoroughly.
Parking the Machine	Steel will expand and contract with variation in temperature. When in operation this process posses no threat, but when equipment is parked, shrinkage could cause severe structural damage. The stress to contraction of the steel is more severe in longer machines. Irrigators 1,500 feet or longer are susceptible to these stresses and may exhibit shrinkage of 8-12 inches when wheel tracks are a problem. Refer to your manufacturer's or operator's manual or follow one of the following methods when parking the machine in the off-season: 1. Park the machine in an area where wheel tracks have been eliminated. 2. Place wooded planks, (2 x 12 inch), over the wheel tracks. Park the machine with the ties centered on the planks. 3. Remove all wheel tracks and run machine 100 - 200 yards. Only operate units (dry) if the temperature is above 40° F. 4. Disconnect machines with spans taller than 8 – 10 feet. Secure spans with chains to allow for contraction during cold weather.

See Table 6 for additional seasonal maintenance procedures.

Table 9. Winterization and Storage Procedures for Agricultural Pumps.

REQUIRED ACTION	PROCEDURE
Paint Pump Housing	Remove all exterior dirt and grime that may trap moisture. Prime and repaint any exposed metal to prevent corrosion.
Flush Suction and Discharge Lines	Flush suction and discharge lines. Check for leaks and replace worn gaskets.
Drain Pump Casing	Remove the lowest plug on pump and drain casing.
Lubricate Bearings	Lubricate bearings according to operation and maintenance manual.
Provide Storage	If possible, keep unit in clean, dry storage area to prevent corrosion.
Seal Open Ports	Seal all open ports to keep out foreign objects, such as insects, rodents, dust, and dirt.
Rotate Drive Shaft	Rotate dive shaft periodically to prevent freeze-up of internal components.

Table 10. Winterization and Storage Producers for Diesel Engines that Power Agricultural Pumps.

STEP	ACTION ITEM	PROCEDURE
1	**Engine Oil and Filter**	Change engine oil and oil filter.
2	**Air Filter**	Service air filter according to operation and maintenance manual.
3	**Cooling System**	Draining and flushing of cooling system is not required if engine will be store for several months. However, for longer than a year, drain the cooling system and refill according to operation and maintenance manual.
4	**Fuel Tank**	Drain the fuel tank and add 1 oz. Of inhibitor to the fuel tank for each 4 gallons of tank capacity.
5	**Crankcase Oil**	Add 1 oz. of inhibitor to the engine crankcase for each quart of crankcase oil.
6	**Air Intake**	Disconnect all air intake piping from the manifold. Pour 3 oz. of inhibitor into the intake system and replace piping.
7	**Start Engine**	Crank engine several revolutions with starter, while NOT allowing the engine to start.
8	**Belts**	Loosen fan and alternator belts to relieve tension. Remove belts if desired.
9	**Batteries**	Remove and clean batteries. Store in cool, dry placed and keep fully charged.
10	**PTO Clutch**	Disengage PTO clutch.
11	**Engine Openings**	Seal all openings on engine with plastic bags and tape. Contact engine dealer for specialized storage kits.
12	**Exposed Metal**	Coat all exposed metal surfaces with grease or corrosion inhibitor.
13	**Engine Exterior**	Clean the exterior of engine and touch-up any scratched or chipped painted surfaces.
14	**Engine Storage**	Store engine in a dry, protected area to prevent additional corrosion. If stored outside, cover with waterproof canvas or other suitable material, and seal ends with a strong waterproof tape.
	Removing Engine From Storage	
1	**Protective Coverings**	Remove all protective coverings from engine. Unseal all openings and remove covering from electrical system.
2	**Batteries**	Remove batteries from storage. Install batteries, and connect the cables.
3	**Belts**	Install new fan and alternator belts (if needed). Adjust belt tensions to appropriate specifications (refer to operation and maintenance manual).
4	**Fuel Tank**	Fill fuel tank.
5	**Start-up Checks**	Perform all start-up checks specified in operation and maintenance manual.
6	**Starting Engine**	1. Crank engine for 20 seconds, while not allowing the engine to start. Then start engine. DO NOT operate the starter more than 30 seconds at a time. Wait at least 2 minutes for starter to cool before trying again. 2. Operate engine at slow idle for several minutes. Warm up engine and check all gauges before initiating pump and placing the engine under load.

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